Airport access and egress trips in an agent-based travel demand model

Carlos Llorca, Qin Zhang, Ana Moreno, Rolf Moeckel

Technical University of Munich

Department of Civil, Geo and Environmental Engineering

Arcisstr. 21, 80333 Munich, Germany

carlos.llorca@tum.de, qin.zhang@tum.de, ana.moreno@tum.de, rolf.moeckel@tum.de

Abstract

Large airports are major components of the transportation systems. Trips to the airport (ground access) or from the airport (ground egress) contribute to the travel demand of the airport surroundings and may overload the infrastructure, with impacts on both airport users and residents in areas near the airport. Given the different travel characteristics of most airport trips (non-habitual travel, luggage is carried, higher willingness to pay for travel, fixed time of arrival, etc.), traditional travel demand models poorly reflect travel behavior to and from the airport. We design a specific sub-model to add this trips to the travel demand generated by an agent-based model. The airport sub-model assigns origin of airport access trips or destination of airport egress trips, based on trip rates obtained from a passenger survey. After that, we assign each trip to a synthetic person (if it is made by residents) or we synthetize a new person (if the trip is made by a visitor). A multinomial logit mode choice model is applied. Lastly, a departure time is sampled from a distribution of airplane arrivals and departures. This model is applied to the airport of Munich, as part of the metropolitan area of Munich (Germany). The addition of airport access and egress trips contributes to a better representation of the demand in the surroundings of the airport.

1. Introduction

Large airports are major components of the transportation systems. Apart from the increasing number of flights, both passengers and workers of the airports generate a significant travel demand on the ground. Trips to the airport (access trips in this paper) or from the airport (egress) contribute to the travel demand of the airport surroundings and may overload the infrastructure, with impacts on both airport users and residents in areas near the airport.

Since trips to the airport are much less frequent than other purposes, they usually are underrepresented in household travel surveys (e.g. airport is not defined as a potential destination or activity in the German Mobilität in Deutschland travel survey (Deutschen Zentrums für Luft- und Raumfahrt (DLR), 2017)). On the other hand, the information about the trip to the airport or from the airport is not described in long-distance travel surveys (e.g. the Travel Survey for Residents of Canada (Statistics Canada, 2014) defines the starting airport for air long-distance trips, but no details about access and egress to that airport are provided). Additionally, most larger airports carry out independent surveys of their own passengers. These data reflect the actual conditions for the surveyed airport but usually do not inform about passengers´ attributes or long-distance trip purposes. Given the different travel characteristics of most airport trips (non-habitual travel, luggage is carried, higher willingness to pay for travel, fixed time of arrival, etc.), traditional travel demand models poorly reflect travel behavior to and from the airport.

Most of the existing literature focused on the estimation of mode choice models. Table 1 summarizes selected airport access mode choice models. In general, these studies were based on airport-specific stated and revealed preference surveys.

Table 1. Mode choice models for access and egress trips to/from airports

Reference	(Gokasar and Gunay, 2017)	(Zaidan and Abulibdeh, 2018)	(Tam et al., 2011)	(Jou et al., 2011)	(Birolini et al., 2019)	(Yazdanpanah and Hosseinlou, 2016)
Airport	Istanbul	Doha	Hong Kong	Taipei	Milan-Bergamo	Tehran
Data collection	Revealed preference	Revealed and stated preferences	Revealed and state preferences	Revealed and state preferences	Revealed preferences	Revealed preferences and attitudes
Method	MNL	Binary Logit for current conditions MNL for future conditions	MNL	Mixed Logit	Mixed Logit	Hybrid Discrete Latent Class
Mode choice set	Car, drop-off, public transport, tax	Car, taxi, (metro)		Car, pick-up/drop-off, taxi, public bus, high speed rail, (metro)	Train, car	Public vs. private modes
Personal attributes	Income, auto ownership			Income, auto ownership		Attitudinal factors
Long-distance trip attributes	Travel party			Only overseas travelers		
Access and egress trip attributes	Distance to airport, Travel time, travel cost, distance from origin to public transport		Travel time reliability / perceived service quality	Out-of-vehicle and in-vehicle travel time, user-friendly nature of the trip Travel cost, number of transfers, etc.	Out-of-vehicle and in-vehicle travel time	
Application		Analyze impact of new metro line	Changes in service attributes and impacts on mode choice	Improvement of travel time of public transport increases it modal share	New direct train services by means of sensitivity analysis	

In general, previous approaches did not account properly for the mutual interaction between airport access and egress trips and the rest of the demand. In most of the cases, road or public transport lines that connect the airport are used by other travel demand segments at the same time. Therefore, the assessment of new policies or infrastructure projects could lead to unrealistic forecasts by ignoring the infrastructure capacity constraints and demand changes on the level of service. Moreover, previous studies usually focused on the connections between the major city and the airport and ignore the rest of the region that belong to the catchment area of the airport. In this paper, we improve the agent-based travel demand model MITO (Moeckel et al., 2019) by including the specific demand of trips to the airport. We apply this model improvement to the metropolitan area of Munich and its airport, which is the second largest airport in Germany.

2. Methodology

The passenger travel demand of airport access and egress is divided into two segments: workers and passengers. In this paper, we only design a model to represent the segment of passengers. The demand generated by workers has been already defined as trips to work in the resident travel demand model. The demand for passenger airport access and egress has certain differences to the existing models for other travel purposes. Firstly, either the origin or the destination of the trip is the airport. Secondly, significant delays of the arrival time at the airport are inacceptable. Thirdly, the trips are made both by residents of the study area (that use the airport to make a long-distance trip) and by visitors (that arrive through the airport to the study area).

We designed an airport travel demand model that is built as an agent-based version of the traditional four-step model. The first three steps (and the departure-time choice) run in parallel with the residents' travel demand model and the fourth step (traffic assignment) is performed as a multi-class assignment for local travel and airport travel (as well as other long-distance travel and freight). The model structure is shown in Figure 1. The different components are explained in the next subsections.

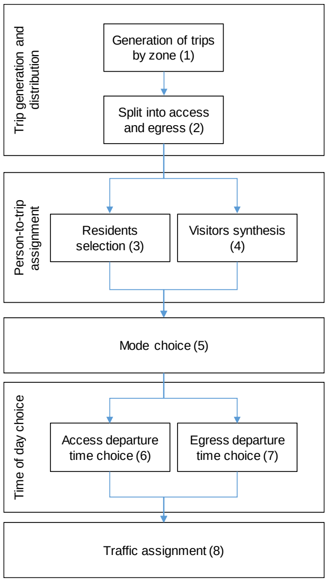


Figure 1. Model structure

2.1. Data collection

The following data sources have been used for the development of this model:

- Aggregated passenger counts by mode and municipality of origin. These data were provided by the travel survey of the Munich airport, for the year 2016.
- Travel time, distance and cost by mode between the airport and the rest of the zones, available from an existing travel demand model.
- Distribution of takeoffs and landings (expressed in number airplane seats) by time of the day, obtained from the website flightradar24.com. They are obtained for a weekday of January, 2019.

2.2. Trip generation, distribution and person-to-trip assignment

This submodule determines firstly the number of trips between the airport and the rest of model zones (step 1 in Figure 1). A regression model to predict the number of trips as a function of production and potential accessibility variables of each municipality is proposed according to equation 1.

$$r_j = e^{b_0+b_1\cdot d_{airport-j}+b_2\cdot is_{city,j}} \tag{1}$$

Where:

- r_j is the rate of trips for the zone/region j as calculated in equation 2
- b_0, b_1, b_2 are coefficients
- $d_{airport\text{-}j}$ is the distance between the airport and the zone/region j
- $is_{city,j}$ is a dummy variable that takes the value of 1 if the zone/region j is a core city (for the Munich study area, we defined 5 core cities)

$$r_j = \frac{p_{j,day}}{n_{residents}} \tag{2}$$

Where:

- $p_{j,day}$ is the number of passengers to the airport originated at zone/region j
- $n_{residents}$ is the population of zone/region j

Assuming that the rate r_j follows a log-normal distribution, the values of the coefficients were estimated and resulted in the values of Table 2.

Table 2. Trip generation model coefficients

Variable	Coefficient	Significance
Intercept (b_0)	-4.911	***
$d_{airport\text{-}j}$ (b_1)	-2.359E-5	***
$is_{city,j}$ (b_1)	1.341	***
Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1		

While the previous regression model was applied at the level of resolution of county (28 counties in our study area), we now apply the same equations at the level of resolution of the model zones (4900 zones in our study area) using equation 3. The generated trips need to be doubled, since they represent only access trips (step 2 in Figure 1).

The number of passengers obtained by equation 3 corresponds to both residents and visitors. Each one of these group will represent a share of the total amount of trips, as expressed in equation 4.

$$p_{j,day} = p_{j,day\ (residents)} + p_{j,day\ (visitors)} = r_j \cdot n_{residents} \cdot 2 \tag{3}$$

$$\begin{gathered} p_{j,day\ (residents)} = s_{residents,j} \cdot p_{j,day} \\ p_{j,day\ (visitors)} = (1 - s_{residents,j}) \cdot p_{j,day} \end{gathered} \tag{4}$$

Where:

- $s_{residents}$ is the share of trips to the airport (or from the airport) that area made by residents of the zone/region j

In absence of more detailed data, we assumed each of those groups represent a 50% of the total amount of trips (i.e. $s_{residents} = 0.5$ for all zones j).

The following steps assign these trips to specific synthetic persons of the MITO model (step 3 for residents and step 4 for visitors in Figure 1). Previous work (Llorca et al., 2019)identified the socio-demographic attributes of long-distance domestic travelers (organized in travel parties). That paper revealed the most common party compositions, personal attributes and predominant income levels of travelers. Based on those distributions, we randomly sample travel parties from the synthetic population that we select to travel. We will sample travel parties until the amount of travelers is equal to $p_{j(residents)}$ persons. We sample again another $p_{j(visitors)}$ and duplicate them (representing the newly arrived visitors that will be added to the synthetic population). Each person is assigned one trip from/to the airport. Figure 2 shows the results measured as the amount of trips by square km and day.

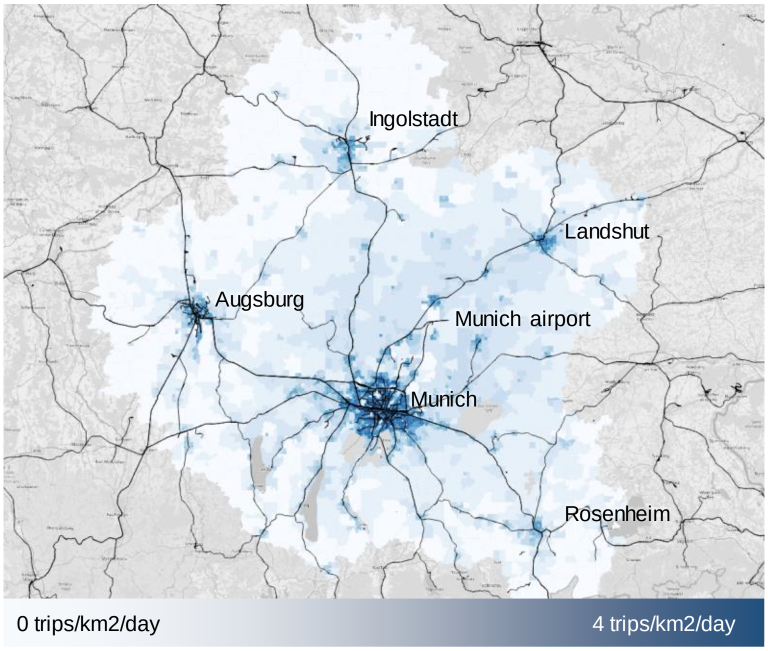


Figure 2. Resulting of trip generation and distribution of trips to and from the Munich Airport

2.3. Mode choice

A mode choice model is estimated for this specific trip purpose (step 5 in Figure 1). A Multinomial Logit Model (MNL) is chosen, including the following modes: train, auto-as-driver and auto-as-passenger. Train includes all types of transit, if at least the commuter trains that connects the airport is used. Auto-as-driver refers to those travelers parking in the airport and the users of car-sharing services. Auto-as-passenger includes “meeters and greeters”, taxi riders and transfer services.

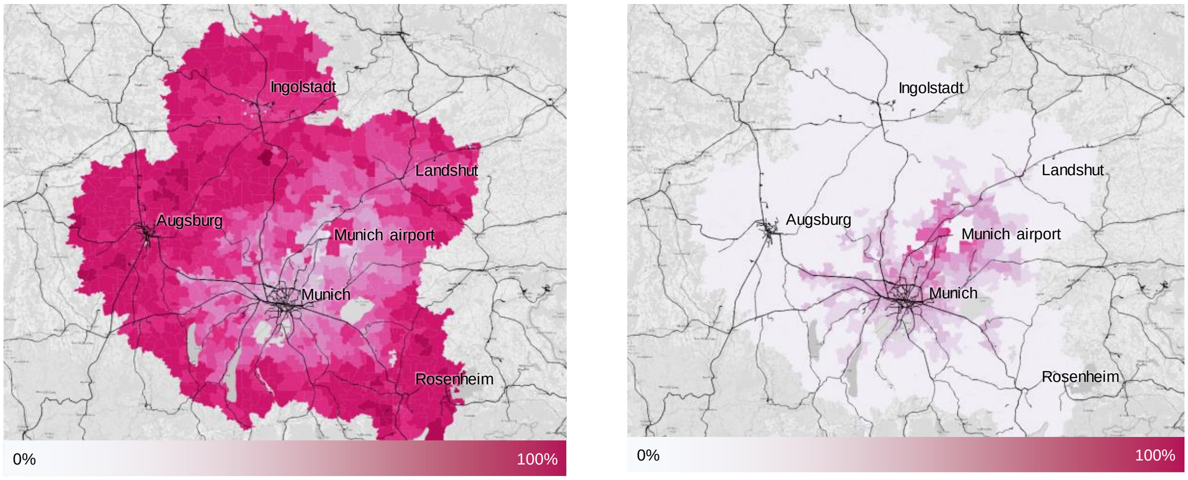
The modes metro, walk and bicycle, which are available for the rest of purposes in MITO, are not included in the airport mode choice set. In absence of detailed data, we assumed the same choice model for the airport access and airport egress trips, and ignore the effect of personal attributes on mode choices.

The results of the mode choice model are shown in Table 2.

Table 3. Mode choice model coefficients

	Auto-as-passenger		Auto-as-driver		Train	
Variable	Coefficient	Significance	Coefficient	Significance	Coefficient	Significance
Intercept	0	***	-1.1461	***	0	***
is_{MVV}	n.s.		n.s.		0.3035	.
$tt_{airport,j}$	n.s.		n.s		-2.0344E-4	***
is_{MVV} is a dummy variable, equal to 1 if the region/zone belongs to the common fare area of the Munich Public Transport Association (Münchener Verkehrs- und Tarifverbund, MVV). $tt_{airport,j}$ the travel time by mode between the airport and the zone j n.s.: not significant Significance codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1						

The results of the mode choice model are shown in Figure 3. The modal shares of auto-as passenger (3A) and train by zone (3B) reveal that auto is chosen by most travelers that start or end their trip in rural areas but also other cities than Munich. On the contrary, public transit riders usually come from close areas or from those regions that are connected to the rail network of the surroundings of Munich (in the so-called MVV area).



A: Modal shares by zone (auto-as-passenger) **B: modal shares by zone (train)**

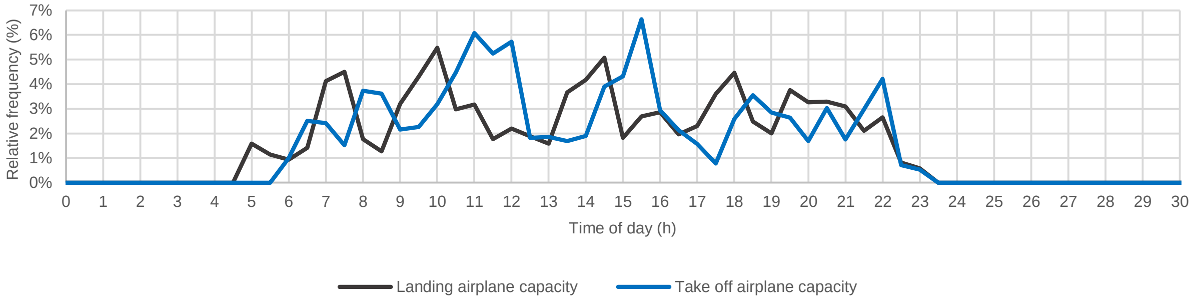
Figure 3. Results of the mode choice model (the map shows the rail network as well)

2.4. Departure time choice

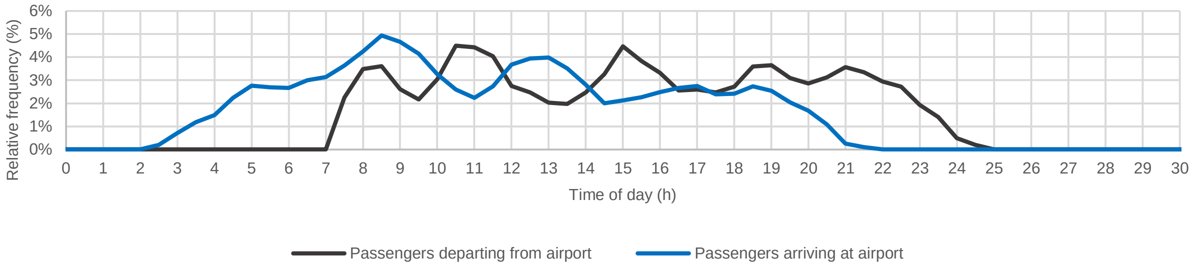
Departure times of the trips are sampled based on the distributions of takeoffs and landings on an average work day:

- To calculate the departure time of access trips, we randomly sample a takeoff time, deduct a uniform random time between 30 and 180 minutes (check-in, security check and access to gate time) and deduct the expected travel time from the origin of the trip using the already selected mode (step 6 in Figure 1).
- To calculate the departure time of egress trips, we sample a landing time and add a uniform random time between 15 and 45 minutes (egress from gate, baggage claim and access to ground transportation time) (step 7 in Figure 1).

The assumption behind this departure and arrival time choice model is that the load of airplanes remains uniform over the day. Figure 4A shows the raw airplane capacity distribution (number of airplane seats arriving and departing from the airport by time bin) and Figure 4B the proposed, smoothed, arriving and departure time distribution for the accessing/egressing travelers, including the above mentioned times for check-in, security, egress from gate etc. As expected and seen in Figure 2B, the flows are highly directional, with a larger share of access trips taking place earlier in the day and egress trips dominating the later part of the day.



A: Incoming and outgoing airplane capacity by time of day on an average working day of January (30 min bin width)



B: Arriving and departing (potential) distribution of passengers for access and egress model (30 min bin width), including estimated check-in and security times (for arriving) and baggage claim times (for departing)

Figure 4. Observed time of day choice and processed distributions

2.5. Feedback between airport and non-airport sub-models

After the previous steps, we discard trips made by residents going to the airport that end after the departure time to the airport. Similarly, we will discard every trip made by residents coming from the airport that start before they arrive at the final destination. As a simplification and in absence of data on visitors' behavior, we add the visitors to the synthetic population, so that they can make additional trips during the simulated day, either before departing to the airport or after arriving from it.

2.6. Traffic assignment

After running the airport and non-airport sub-models, we assign the resulting trips to the network jointly. For access and egress airport trips, the following rules are taking into account (step 8):

- For each travel party (of *n* travelers) that choses auto-as-driver, we assign one car trip to one of the travel party members and *n-1* car passenger trips (that do not add vehicles to the assignment).
- For each travel party (of *n* travelers) that chooses auto-as-passenger, we assign one car trip to one of the travel party members and *n-1* trips passenger trips (not adding vehicles). We assume that this trip is either made by taxi or someone else picks-up/drops-off the travel party at the airport.
- For each travel party (of *n* travelers) that choses train, we assign n trips made by train.

3. Applications

The presented models add a travel segment that was not available in the MITO model (as in most other existing travel demand models). Firstly, this model improves the fidelity of the simulation in the zones that are close to the airport where the new additional demand contributes substantially to the use of the transportation system.

Secondly, it allows the simulation of scenarios that affect ground access and egress to/from the airport. In particular, the quantification of the demand to the airport is relevant to test the impact of public transport extensions or improvements (the region of Munich is planning to extend an additional commuter train line to the airport, and to provide express train services between airport and city center). Moreover, the potential of new modes of transportation, such as Transport Network Companies (TNC) or Urban Air Mobility (UAM) for the access and egress to airports could be analyzed.

4. Conclusion

In this paper, the split of access and egress trips to the airport between residents and visitors was simplified. The 50/50 split reflected the proportions that were reported for the entire catchment area, but it is expected that this percentage varies depending on the land uses of the origin or final destination of the trips. For instance, very touristic areas, hotels or conference centers will be visitor attractors rather than resident trip generators. Unfortunately, none of the available datasets inform about the different visitor/resident traveler ratios.

Although the developed model contributes well to the first applications mentioned in section 3, there is further work needed to use this model for new scenarios, especially if they involve the introduction of new modes. The mode choice models developed in this paper were based on aggregated data sources. Consequently, they did not include any of the personal and trip attributes that usually affect the choices, such as income or travel party size. Depending on the desired application, transport modelers should improve or substitute the current mode choice model. For instance, we propose to used incremental logit approaches, if a new mode is added to the choice set or some improvements are done in the existing ones. Alternatively, new mode choice models could be estimated based on stated preference surveys.

The model for access and egress trips to the Munich airport added around 44,000 trips to the travel demand of the metropolitan area. Despite the relative low proportion, with respect of the total travel demand (around 8,000,000 trips), they are very relevant in the vicinity of the airport.

5. Acknowledgement

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